



UNIVERSITI PUTRA MALAYSIA

**EFFECTS OF ALUMINIUM TOXICITY ON ROOT MORPHOLOGY
AND PHYSIOLOGY OF TWO MAIZE HYBRIDS**

TEGUH PRASETYO

FP 2007 20

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**MASTER OF SCIENCE
UNIVERSITI PUTRA MALAYSIA**

2007



**EFFECTS OF ALUMINIUM TOXICITY ON ROOT MORPHOLOGY AND
PHYSIOLOGY OF TWO MAIZE HYBRIDS**

By

TEGUH PRASETYO

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of the Requirements for the Degree of Master of Science**

June 2007



DEDICATION

To my Parents, for the constant prayer, support and the educational opportunities that they gave me, and to my brothers and sister

“[Al-A’râf 7 : 58] The vegetation of a good land comes forth (easily) by the Permission of its Lord; and that which is bad, brings forth nothing but (a little) with difficulty. Thus do We explain variously the Ayât (proofs, evidences, verses, lessons, signs, revelations, etc.) for a people who give thanks”.



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment
of the requirements for the degree of Master of Science

**EFFECTS OF ALUMINIUM TOXICITY ON ROOT MORPHOLOGY AND
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By

TEGUH PRASETYO

June 2007

Chairman : Associate Professor Zakaria Wahab, PhD

Faculty : Agriculture

Acid soils in Malaysia account for 72% of the country that was classified under Ultisols and Oxisols. Crop production is not favorable in highly weathered Ultisols and Oxisols, due to aluminium (Al) and manganese (Mn) toxicities as well as calcium (Ca) and magnesium (Mg) deficiencies. Acid soils with high Al saturation ($> 60\%$) induce water stress and retards plant growth. Al toxicity and water stress affects every aspect of plant growth, including the anatomy, morphology, physiology and biochemistry. Therefore, a detail understanding of the physiological characteristics of Al stress, will lead to improvement of maize (*Zea mays* L.) with tolerance to Al that can be grown on Ultisols and Oxisols.

Three experiments were conducted to study the effects of aluminium toxicity on root morphology and physiology of two maize hybrids (Putra J-58 and C-7). Experiments were conducted in the laboratory and at Field two, Faculty of Agriculture, Universiti Putra Malaysia. The experiments were conducted to study the effect of Al on seed germination, short-term effect of Al on root structure and effect of high Al



concentrations on maize growth. The experimental designs were randomized complete block design in factorial arrangement, and replicated three times.

Overall results showed that maize seeds were impermeable to Al, even though seeds were soaked in 300 μM Al for 8 h, the seeds when sliced and stained with 0.2% hematoxylin showed that the embryo was not stained. Moreover, seed germination was normal when soaked in Al solution, but after germination, root growth was restricted and root tip became brown, stubby, with lesions on the root surface. The total root length of C-7 was significantly longer than Putra J-58.

Hematoxylin staining showed that tolerance level of Putra J-58 was considered as *intermediate* tolerance to Al, while C-7 was *sensitive* to Al. Al uptake appears to take place within 30 min, and based on the root morphological observations, Al disrupted root cells within 24 h as indicated by lesions in the cortex tissue of the root tip.

High Al concentrations (278 and 556 μM Al) inhibited root growth as well as root branching and induced water stress symptoms. After two days in the Al solution, leaves showed interveinal chlorosis, a symptom of Mg deficiency and supported by result of leaf analysis. This symptom was observed on plant grown in solutions with 278 and 556 μM Al. Ca content in the shoot of maize grown in 0 and 556 μM Al were 8.81 and 4.41 $\mu\text{g/g}$ of DM, respectively. Moreover, Mg content in the shoot of maize grown in 0 and 556 μM Al were 5.51 and 2.33 $\mu\text{g/g}$ of DM, respectively. After six days in the nutrient solution containing 556 μM Al, root and shoot dry matter reduced by 61.1% and 34.8%, respectively, compared to control. In addition,



stomatal resistance increased by 84.6% and transpiration rate was reduced 41.8% by 556 μM Al, respectively, compared to control.

Al toxicity induced root lesions, stubby roots and deep-cracking on the epidermal tissue of the roots. However, the degree of root inhibition or root damage and the decreasing plant physiological activities were dependent on the level of Al present. Maize root growth appears to show a linear or almost exponential response to Al toxicity.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

**KESAN KETOKSIKAN ALUMINIUM TERHADAP MORFOLOGI AKAR
DAN FISILOGI DARIPADA DUA HIBRID JAGUNG**

Oleh

TEGUH PRASETYO

Jun 2007

Pengerusi : Profesor Madya Zakaria Wahab, PhD

Fakulti : Pertanian

Tanah berasid di Malaysia dianggarkan 72% daripada tanah di negara ini dan diklasifikasikan sebagai Ultisol dan Oksisol. Pengeluaran tanaman tidak begitu baik di tanah Ultisol dan Oksisol yang diakibatkan oleh ketoksikan aluminium (Al) dan mangan (Mn) dan juga kekurangan kalsium (Ca) dan magnesium (Mg). Tanah yang berasid dengan ketepuan Al yang tinggi (>60%) menggalakkan ketegasan (kekurangan) air dan merencatkan pertumbuhan tanaman. Ketoksikan Al and kekurangan air memengaruhi setiap aspek tumbesaran tanaman, termasuk anatomi, morfologi, fisiologi and biokimia. Oleh itu, kefahaman yang mendalam tentang ciri-ciri fisiologi kesan Al akan menghasilkan pembaikan jagung (*Zea mays* L.) supaya toleran terhadap Al dan boleh ditanam di Ultisol dan Oksisol.

Tiga kajian telah dijalankan untuk mengkaji kesan-kesan ketoksikan aluminium terhadap morfologi akar dan fisiologi daripada dua hibrid jagung (Putra J-58 dan C-7). Kajian telah dijalankan di makmal dan di Ladang 2, Fakulti Pertanian, Universiti Putra Malaysia. Kajian telah dijalankan untuk mengkaji kesan Al pada percambahan

biji benih, kesan jangkamasa pendek Al terhadap struktur akar, dan kesan kepekatan Al yang tinggi terhadap pertumbuhan tanaman. Rekabentuk kajian yang digunakan adalah rekabentuk penuh rawak lengkap dalam bentuk faktorial dengan tiga kali replikasi.

Keputusan keseluruhan menunjukkan biji benih jagung tidak telap terhadap Al, walaupun biji benih yang direndam ke dalam 300 μ M Al selama 8 jam. Biji benih dipotong dan di letakkan dengan 0.2% hematoksin, tidak menunjukkan kesan pengambilan hematoksin. Tambahan lagi, percambahan biji benih adalah normal di dalam larutan Al tetapi selepas percambahan, pertumbuhan akar dihadkan oleh Al. Hujung akar bertukar menjadi warna coklat, terencat dan melecur di permukaan hujung akar. Jumlah panjang akar C-7 lebih panjang secara signifikan berbanding Putra J-58.

Pelekatan hematoksin menunjukkan tahap toleran Putra J-58 dianggap sebagai pertengahan, sementara C-7 adalah sensitif terhadap Al. Pengambilan Al mengambil masa 30 minit dan berdasarkan kepada pemerhatian morfologi, Al merosakkan sel akar dalam masa 24 jam yang ditunjukkan oleh kesan melecur dalam tisu kortek di hujung akar.

Kepekatan Al yang tinggi (278 dan 556 μ M Al) merencat pertumbuhan dan percabangan akar dan menunjukkan simptom ketegasan air. Selepas dua hari dipindahkan kepada larutan nutrien, daun menunjukkan simptom klorosis seperti kekurangan Mg yang disokong oleh keputusan analisis daun. Simptom ini dapat dilihat

bagi jagung yang ditanam dengan 278 dan 556 μM Al. Kandungan Ca dalam pucuk pokok jagung apabila ditanam dalam 0 dan 556 μM Al adalah masing-masing 8.81 dan 4.41 $\mu\text{g/g}$ berat kering. Selain itu kandungan Mg dalam pucuk pokok jagung apabila ditanam dalam 0 dan 556 μM Al adalah masing-masing 5.51 dan 2.33 $\mu\text{g/g}$ berat kering. Selepas enam hari dalam larutan nutrien yang mengandungi 556 μM Al, berat kering akar dan pucuk masing-masing berkurang sehingga 61.1% dan 34.8% berbanding dengan kawalan. Selain itu, rintangan stomata meningkat 84.6% dan kadar transpirasi mengurang sebanyak 41.8% berbanding dengan kawalan.

Ketoksikan Al menggalakkan pelecuran akar, akar bantut dan rekahan pada tisu epidermis. Darjah kerosakan akar atau pengurangan aktiviti-aktiviti fisiologi pokok bergantung kepada tahap kepekatan Al. Tumbesaran akar pokok jagung kelihatan menunjukkan sifat linear atau hampir eksponential terhadap kesan ketoksikan Al.

ACKNOWLEDGEMENTS

Praise is to Allah, the Lord of the universe, He who taught man the use of pen and He taught him what he knew not.

I would like to express my sincere appreciation and gratitude to Assoc. Prof. Dr. Zakaria Wahab, chairman of my supervisory committee, for his attentive supervision, unfailing guidance, consistent encouragement, patience, useful discussions and devotion during the course of this study. His constructive criticisms and valuable comments during the preparation of this manuscript are highly valued. Besides his guidance and kindness, he help to fulfill all the necessary facilities that made my study successful and fruitful.

I am also indebted to Assoc. Prof. Dr. Abdul Ghani Yunus, my supervisory committee, for his attentive supervision, unfailing guidance, and provided me laboratory facilities to do my job far more effectively. Besides his advice was most valuable.

I also would like to thank Prof. Dr. Ghizan Saleh, for supplying Putra J-58 seeds; Dr. Askif Pasaribu, for supplying C-7 seeds; and Prof. Shamshuddin Jusof, for acid soils information. My sincere gratitude and thanks go to my truly brother Dr. Abdulkadir Iman Shah Mohamoud for his valuable advice and editing of this manuscript.



I am also grateful to the laboratory and field staffs/personnel of the Departments of Crop Science, Land Management and Plant Protection, Faculty of Agriculture, UPM, in particular En H. Khairi Kandar, En. Mohd Shahril b. Abdul Rahman, En. Rahman, En. Daud Mustam, Pn. Asiah bt. Othman, Pn. Fouzaiah Sulaiman, Pn. Hajjah Maininah Tahir and others for their help and cooperation during laboratory analysis.

I will not forget the patience of my mother Sukartinem, my father Suratman, my brother Joko Suzatmiko, Indarto Priyo Utomo, my sister Syahfitri Utami and my brother in law Suwarsono, other friends particularly Bambang Prasetyo, A. Sumargono, Anwar Fitrianto for their frequent contact, moral support and constant encouragement, which made life easy throughout my study. Eventually, I am grateful to Fatih Abdul Hakim and Mohammad Fuad bin Rahman for their help to me while conducting the experiments.



I certify that an Examination Committee has met on 26 June 2007 to conduct the final examination of Teguh Prasetyo on his Master of Science thesis entitled “Effects of Aluminium Toxicity on Root Morphology and Physiology of Two Maize Hybrids”, in accordance with Universiti Pertanian Malaysia (Higher Degree) Act. 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Member of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

TEGUH PRASETYO

Date : 24 July 2007



TABLE OF CONTENTS

	Page
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	vi
ACKNOWLEDGEMENTS	ix
APPROVAL	xi
DECLARATION	xiii
LIST OF TABLES	xvii
LIST OF FIGURES	xix
LIST OF ABBREVIATIONS	xxiii
 CHAPTER	
 1 INTRODUCTION	 1
 2 LITERATURE REVIEW	
2.1 Acid Soils in Malaysia	3
2.2 Maize Growth in the Malaysian Acid Soils	4
2.3 Aluminium in Soils	4
2.4 Aluminium in Aqueous Solutions	5
2.5 Differential Toxicity among Aluminium Ion Species	6
2.6 Biological Effect of Aluminium Toxicity on Plant Growth	7
2.6.1 Effect of Aluminium on Root Structure	7
2.6.2 Effect of Aluminium on Physiology of the Plant	10
2.7 Effect of Aluminium Toxicity on Water Stress	13
2.8 Summary of the Effects of Aluminium Toxicity on Plant Growth	16
 3 GENERAL MATERIALS AND METHODS	
3.1 Experiment Set-up	17
3.2 Plant Material	17
3.3 Growth Media Preparation	17
3.4 Aluminium Treatment	18
3.5 Seed Germination Percentage	19
3.6 Root Growth Measurement	19
3.7 Root Morphology	19
3.8 Root Histology	19
3.9 Scanning Electron Microscopy	22
3.10 Hematoxylin Staining	22
3.11 Stomatal Resistance and Transpiration	23
3.12 Leaf Relative Water Content	24
3.13 Leaf Area	25
	xiv

3.14	Biomass Production	25
3.15	Macro Nutrient Composition	25
4	EFFECT OF ALUMINIUM ON SEED GERMINATION OF MAIZE	
4.1	Introduction	27
4.2	Objectives	27
4.3	Materials and Methods	28
4.3.1	Experimental Treatment and Design	28
4.3.2	Seed Germination Percentage	28
4.3.3	Seed Staining with Hematoxylin	29
4.3.4	Primary Root Growth	29
4.3.5	Root Morphology	29
4.3.6	Scanning Electron Microscopy	29
4.4	Results	30
4.5	Discussion	42
4.6	Conclusion	45
5	SHORT-TERM EFFECT OF ALUMINIUM ON ROOT STRUCTURE OF MAIZE	
5.1	Introduction	46
5.2	Objectives	47
5.3	Materials and Methods	47
5.3.1	Experimental Treatment and Design	47
5.3.2	Hematoxylin Staining	49
5.3.3	Root Morphology	50
5.3.4	Root Histology	51
5.3.5	Scanning Electron Microscopy	51
5.4	Results	51
5.5	Discussion	63
5.6	Conclusion	65
6	EFFECT OF HIGH ALUMINIUM CONCENTRATION ON MAIZE GROWTH	
6.1	Introduction	66
6.2	Objectives	67
6.3	Materials and Methods	68
6.3.1	Experimental Treatment and Design	68
6.3.2	Root Growth Measurement	68
6.3.3	Stomatal Resistance and Transpiration	69
6.3.4	Leaf Relative Water Content	69
6.3.5	Leaf Area	69
6.3.6	Biomass Production	69
6.3.7	Macro Nutrient Composition	69
6.3.8	Root Morphology	70
6.3.9	Scanning Electron Microscopy	70
6.4	Results	70
6.5	Discussion	107
6.6	Conclusion	113

7	GENERAL DISCUSSION AND CONCLUSION	114
	REFERENCES	118
	APPENDICES	128
	BIODATA OF THE AUTHOR	137



LIST OF TABLES

Table	Page
2.1 Summary of organic acids released by some of plant species	12
2.2 Summary of the effects of Al toxicity and water stress on plant growth	16
3.1 Composition of modified solutions A, B and C	18
4.1 Effect of soaking and Al concentrations on seed germination percentage at the first day after incubation	31
5.1 Staining patterns and Al tolerance	50
5.2 Staining pattern of hematoxylin on roots of two maize hybrids Putra J-58 and C-7	55
6.1 Effect of aluminium on root length (cm) of hybrids Putra J-58 and C-7 on the fifth day after exposure in Al solution	73
6.2 Effect of modified solutions on stomatal resistance ($s\ cm^{-1}$) of hybrids on the fifth day after exposure in Al solution (Data from original mean)	75
6.3 Effect of modified solutions on stomatal resistance ($s\ cm^{-1}$) of hybrids on the fifth day after exposure in Al solution (Data from transformed mean)	75
6.4 Effect of modified solutions and aluminium on leaf area (cm^2) on the sixth day after exposure in Al solution	80
6.5 Effect of modified solutions and aluminium on root/shoot dry weight ratio on the sixth day after exposure in Al solution	84
6.6 Effect of modified solutions and aluminium on nitrogen in shoot (% DM) on the sixth day after exposure in Al solution	86
6.7 Effect of modified solutions and aluminium on phosphorus in shoot (% DM) on the sixth day after exposure in Al solution	87
6.8 Effect of modified solutions and aluminium on potassium in shoot ($\mu g/g\ DM$) on the sixth day after exposure in Al solution	88



6.9	Effect of modified solutions and aluminium on calcium in shoot ($\mu\text{g/g DM}$) on the sixth day after exposure in Al solution	90
6.10	Effect of maize hybrids and aluminium on magnesium in shoot ($\mu\text{g/g DM}$) on the sixth day after exposure in Al solution	91
6.11	Effect of modified solutions and aluminium on magnesium in shoot ($\mu\text{g/g DM}$) on the sixth day after exposure in Al solution	92
6.12	Relationship of macro elements (Y) and Al concentrations (X) in shoot on the sixth day after exposure in solution B	93



LIST OF FIGURES

Figure	Page
3.1 WinRHIZO 2002c PC-Program Instrument Unit	20
3.2 3D Microscope, HIROX H-Scope KH-2700	20
3.3 Procedure for root histological study	21
3.4 Baltec CPD 030 for critical point dryer, and gold coater JEOL JFC-1600 Auto fine coater	23
3.5 Steady State Porometer Li-1600	24
4.1 Seed germination percentage of Putra J-58 and C-7 up to four days after incubation	31
4.2 Photomicrographs of hematoxylin staining on seeds of Putra J-58 after various duration of soaking in different Al concentrations	33
4.3 Photomicrographs of hematoxylin staining on seeds of C-7 after various duration of soaking in different Al concentrations	34
4.4 Primary root length of Putra J-58 and C-7 on the fourth day after incubation in Al solution	35
4.5 Effect of aluminium on primary root growth on the fourth day after incubation in Al solution	36
4.6 Photomicrographs of morphological changes induced by Al on root surface of Putra J-58 at fourth day after incubation	37
4.7 Photomicrographs of morphological changes induced by Al on root surface of C-7 at four day after incubation	38
4.8 Morphological changes induced by Al on root surface of Putra J-58 on the fourth day after incubation	40
4.9 Morphological changes induced by Al on root surface of C-7 on the fourth day after incubation	41
5.1 Seed germination over distilled water	48
5.2 Hematoxylin staining of Putra J-58, after exposure for various times in Al solution (5, 10, 20 and 40 μ M Al)	52



5.3	Hematoxylin staining of C-7, after exposure for various times in Al solution (5, 10, 20 and 40 μ M Al)	53
5.4	Hematoxylin staining on Putra J-58 and C-7 after 24 h exposure to treatment solution with Al concentrations (5, 10, 20 and 40 μ M Al)	54
5.5	Photomicrographs of morphological changes induced by Al on root tip of Putra J-58 after various times of exposure in Al solution	56
5.6	Photomicrographs of morphological changes induced by Al on root tip of C-7 after various times of exposure in Al solution	57
5.7	Photomicrographs of maize hybrids Putra J-58 and C-7 grown for 24 h in Al solution	59
5.8	Morphological changes induced by Al on root surface of Putra J-58	61
5.9	Morphological changes induced by Al on root surface of C-7	62
6.1	Effect of Al concentrations on root length on the first to fifth day after exposure in Al solution	72
6.2	Effect of Al concentrations on root length on the fifth day after exposure in Al solution	72
6.3	Effect of aluminium on stomatal resistance on the fifth day after exposure in Al solution (Data from original mean)	74
6.4	Effect of aluminium on stomatal resistance on the fifth day after exposure in Al solution (Data from transformed mean)	75
6.5	Effect of aluminium on transpiration rate on the fifth day after exposure in Al solution (Data from original mean)	77
6.6	Effect of aluminium on transpiration rate on the fifth day after exposure in Al solution (Data from transformed mean)	77
6.7	Effect of aluminium on leaf relative water content on the fifth day after exposure in Al solution	78
6.8	Leaf area of maize hybrids on the sixth day after exposure in Al solution	79
6.9	Root dry weight (g/plant) of maize hybrids on the sixth day after exposure in Al solution	81

6.10	Effect of aluminium on root dry weight (g/plant) on the sixth day after exposure in Al solution	81
6.11	Effect of modified solutions on shoot dry weight (g/plant) on the sixth day after exposure in Al solution	82
6.12	Effect of aluminium on shoot dry weight (g/plant) on the sixth day after exposure in Al solution	83
6.13	Root/shoot dry weight ratio of maize on the sixth day after exposure in Al solution	84
6.14	Nitrogen in shoot (% DM) of maize hybrids on the sixth day after exposure in Al solution	86
6.15	Calcium in shoot ($\mu\text{g/g}$ DM) of maize hybrids on the sixth day after exposure in Al solution	89
6.16	Relationship of macro elements and Al concentrations in shoot on the sixth day after grown in solution B	93
6.17	Magnesium deficiency symptom of hybrids Putra J-58 and C-7 leaves after six days exposure in Al solution	94
6.18	Photomicrographs of morphological changes induced by Al on root apex (root tip and maturation zone) of Putra J-58 after 24 hours exposure in Al solution	97
6.19	Photomicrographs of morphological changes induced by Al on root apex (root tip and maturation zone) of C-7 after 24 hours exposure in Al solution	98
6.20	Photomicrographs of morphological changes induced by Al on root apex (root tip and maturation zone) of Putra J-58 after six days exposure in Al solution	99
6.21	Photomicrographs of morphological changes induced by Al on root apex (root tip and maturation zone) of C-7 after six days exposure in Al solution	100
6.22	Effect of modified solutions and Al on root performance of Putra J-58 after six days exposure in Al solution	101
6.23	Effect of modified solutions and Al on root performance of C-7 after six days exposure in Al solution	102
6.24	Morphological changes induced by Al on root surface of Putra J-58 after six days exposure in Al solution	105



6.25	Morphological changes induced by Al on root surface of C-7 after six days exposure in Al solution	106
7.1	Schematic representation of mechanism of Al toxicity on maize	116



LIST OF ABBREVIATIONS

ABA	abscisic acid
ANOVA	analysis of variance
APX	ascorbate peroxidase
CAT	catalase
CEC	cation exchange capacity
<i>cv</i>	coefficient of variation
d	day
DHAR	dehydroascorbate reductase
DM	dry matter
DNMRT	Duncan new multiple range test
FAA	formalin acetic acid alcohol
FAO	food and agriculture organization
FC	field capacity
GPX	glutathione peroxidase
GR	glutathione reductase
h	hour
H ₂ O ₂	hydrogen peroxide
ha	hectare
Hg	hydrargyrum (mercury)
LSD	least significant difference
MPa	mega pascal
MT	microtubule
M.T.	metric ton

